UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Safe and Sustainable By Design

2627-2-F7603Q009

Aims

The course Safe and Sustainable by Design aims to provide students with the theoretical and practical knowledge required to evaluate or design production processes with minimized health and environmental impact, within safety-sustainability-oriented and innovation-driven frameworks. The course aims to integrate hazard, safety, safety assessment, organic chemistry principles, considering industrial chemistry concepts, green chemistry metrics, and circular bioeconomy strategies together with in line with the Safe and Sustainable by Design (SSbD)
approach. The different concepts will be integrated to support a comprehensive understanding of the interconnections among sustainability, safety, and environmental impact.

The objectives of the course are divided as follows:

i) Knowledge and understanding
The main goal will be the capability to understand the theoretical, the principles and the procedures that allow to link safety and sustainability within production processes or novel products development.
In detail the following are the main objectives

- Acquire the theoretical knowledge necessary to understand the relationships between production processes, potential pollutant emissions, and their effects on human health.
- Acquire the procedural knowledge required to estimate the impacts on an exposed population resulting from the presence of pollutants in a reference environment.
- Gain familiarity with the core procedures of toxicological risk assessment and the integration of interdisciplinary information (chemical, physical, and biological) within the Safe and Sustainable by Design framework.
- understand the fundamental principles of organic chemistry relevant to industrial and environmental processes;
- describe the main characteristics of chemical processes in industrial chemistry;
- explain the 12 principles of green chemistry and their role in sustainable chemical design;
- understand and interpret key sustainability metrics (Atom Economy, Carbon Efficiency, E-Factor);
- define the concepts of circular bioeconomy and SSbD and their relevance to modern chemical innovation.

ii) Applying knowledge and understanding
The information acquired during the course are expected to be applied within safety and sustainability context. In detail the following are the key points expected to be reached at the end of the course:

- Ability to identify and apply data from literature or databases to assess potential risks to human health when evaluating production processes or innovative products.
- apply green chemistry principles to the analysis of chemical processes;
- use sustainability metrics to evaluate the environmental performance of reactions and processes;
- interpret industrial case studies in terms of efficiency, waste reduction, and resource sustainability;
- relate chemical design choices to circular bioeconomy strategies and SSbD principles.

iii) Making judgements
At the end of the course the students the course will give the student the instruments to make critical judgement of safety and sustainability approaches and results.
In detail these are the specfic objectives

- Ability to assess impacts on humans and to formulate potential mitigation interventions and environmental compatibility strategies.
- Ability to critically analyze literature data; development of an overall vision by integrating interdisciplinary knowledge.
- critically assess the environmental impact and sustainability of chemical processes;
- compare alternative synthetic routes based on green chemistry criteria and quantitative metrics;
- evaluate the coherence of industrial processes with circular bioeconomy and SSbD frameworks;
- identify trade-offs between efficiency, safety, and sustainability in chemical design.

iv) Communication skills
By the end of the course, students will be able to

- use appropriate scientific terminology in safety assessment, green chemistry and industrial chemistry;
- clearly explain hazard definition procedures, exposure assessment, safety approaches, chemical processes, sustainability metrics, and design strategies;
- communicate results of process evaluation using structured scientific language;
- present and discuss case studies in a clear and coherent manner

Learning Skills
By the end of the course, students will be able to:

- integrate knowledge from organic chemistry, industrial chemistry, and sustainability science;
- integrate knowledge from toxicological process to hazard definition and safety assessment;
- independently deepen their understanding of safe, green and sustainable chemistry approaches;
- critically analyze new developments in circular bioeconomy and SSbD frameworks;
- apply acquired tools to future studies and interdisciplinary contexts in chemical sciences.

Contents

The course “Safe and sustainable by design” consists in lectures designed to provide a clear understanding of the complex network of interactions linking production process (green chemistry) circular bio-economy and the potential unwanted impacts on human and environmental health. The overall concept that will guide all the lectures is the safe and sustainable by design framework to which other relevant frameworks and tools will be related.
The course will be taught in English.

Detailed program

The course "Safe and sustainable by design" aims to provide the following specific knowledge that are integrated in the course as a holistic approach.

Safety:
The program will cover specific aspects that are required to understand the potential impacts on human health and to integrate it in the Safe and sustainability framework:
• The concept of inherent hazard of molecules or compounds and methods for its quantification;
• The concept of exposure of populations;
• Assessment methods for the effects of molecules or compounds within the general framework of a risk assessment procedure;
• Definition and assessment of effects in the context of European reference procedures (such as those defined by ECHA and EFSA);
• Understanding of the steps for an integrated assessment of commercial properties alongside safety and sustainability evaluations.

Sustainability and green chemistry.
The program will cover specific aspects required to evaluate the possible reduction of unwanted impact by innovating production processes:
• Fundamental concepts of organic chemistry relevant to sustainable chemical processes
• Introduction to the concept of chemical processes in industrial contexts
• Detailed presentation of the twelve principles of green chemistry as a framework for designing safer and more sustainable chemical products and processes
• Overview of the circular bioeconomy concept as an integrated approach combining renewable resources
• Analysis of green chemistry principles within the SSbD framework

All the concepts will be integrated in case studies analysis that will allow to apply and review the knowledge acquired in specific (real o theoretical) cases.

Prerequisites

The required prerequisites are those set for admission to and enrollment in the degree program. However, basic knowledge of organic and inorganic chemistry and basic notions of thermodynamics is expected.

Teaching form

The course consists of 8 CFUs (ECTS credits) for a total of 80 hours, structured as follows:

32 2-hour lectures (64 hours total), Frontal Teaching (Delivered Didactics): delivered both in-person and remotely (up to 24 total hours). Lectures, based on slides presentation, may begin with standard delivered teaching but may transition into an interactive format.

8 2-hour sessions (16 hours total), Interactive Teaching (Interactive teaching): delivered in-person (and potentially grouped into 4-hour sessions). During these sessions, students will work under the professors' supervision to apply the concepts covered in class to theoretical or real-world case studies.

Both Frontal and Interactive teaching sessions may utilize online audience engagement tools such as Wooclap or Socrative.

Textbook and teaching resource

Teaching resources:
Lecture presented slides and other e-learning shared material.

Possible textbooks to be considered for more focused information:

- Toxicology. The basic science of poison. Cassarett and Doull's. Mc Graw Hill Education
- Health Risk Assessment of Environmental Chemicals. Masami Ishido. Springer
- Life Cycle Analysis Based on Nanoparticles Applied to the Construction Industry. Mercader-Moyano and Porras-Pereira. Springer

Semester

The course is planned during the first semester.

Assessment method

The final exam will be an oral interview with grades for successful evaluations between 18 and 30/laude. The oral exam is designed to verify the understanding of theoretical concepts presented in class, as well as the ability to apply them to theoretical cases. Students must demonstrate the capacity to autonomously develop and adopt the procedures taught, alongside proficiency in using appropriate disciplinary terminology.

The following criteria are considered for the evaluation:

1. conceptual knowledge and understanding
2. ability to apply knowledge and understanding
3. communication and argumentation skills
4. learning, self-assessment, and self-regulation skills

As a guideline the following grade are expected:

- Grade < 18
  Knowledge and Understanding: The student only partially identifies the characteristics of the concepts. The connections between the concepts are fragmented and poorly supported by theoretical knowledge. Ability to apply knowledge and understanding: The student identifies only a few relevant elements in a phenomenon, unable to integrate them into a coherent analysis. Communication and Argumentation Skills: In the oral exam, the student develops a basic argument, lacking logical structure and characterized by numerous expository inaccuracies.
  Learning, self-assessment, and self-regulation skills: The student is able to reconstruct only some aspects of their learning and professional development journey.

- Grade 18-22
  Knowledge and Understanding: The student recognizes and explains most of the conceptual features and is able to provide a relatively coherent explanation, albeit with some inaccuracies. Theoretical references are present but not always rigorously. Ability to apply knowledge and understanding: The student is able to

recognize a significant number of elements and provide a partial explanation, while highlighting some gaps in the analysis. Communication and argumentation skills: In the oral exam, the student constructs a basic argument, with a minimal structure but with some inaccuracies. Learning, self-assessment, and self-regulation skills: The student demonstrates a basic awareness of their learning path, managing to draw essential connections between learning experiences, albeit with some inaccuracies.

- Grade 23-27
  Knowledge and Understanding: The student demonstrates a thorough understanding of conceptual characteristics. In the oral exam, explanations are well-articulated and supported by an appropriate use of theoretical references. Ability to apply knowledge and understanding: The student accurately identifies the essential elements of a phenomenon. The application of knowledge occurs with methodological rigor that is not always solid. Communication and argumentation skills: In the oral exam, the student develops a coherent and well-organized
  argument, demonstrating good command of language and a solid logical-argumentative structure. Communication is clear and effective. Learning, self-assessment, and self-regulation skills: The student analyzes his or her learning journey in a clear and structured manner, highlighting significant relationships between the various developmental stages and demonstrating a good capacity for critical reflection.

- Grade 28-30
  Knowledge and Understanding: The student demonstrates a thorough mastery of concepts, articulating complex connections and providing comprehensive explanations. Theoretical references are used with relevance and rigor. Ability to apply knowledge and understanding: The student demonstrates an advanced ability to analyze a phenomenon, comprehensively identifying and interpreting all salient elements. Knowledge is applied with methodological rigor, supported by solid and detailed argumentation. Communication and argumentation skills: In the oral exam, the student develops a solid and detailed argument, with a rigorous logical structure and a high level of textual coherence. The presentation is fluent and wellstructured. Learning, self-assessment, and self-regulation skills: The student demonstrates an advanced capacity for selfreflection, developing a detailed and in-depth analysis of their learning and professional development journey. The connections between learning experiences and theoretical concepts are clear, coherent, and rigorous.

Office hours

Students' reception is open by prior appointment to be required by email to the professor

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | INDUSTRY, INNOVATION AND INFRASTRUCTURE | SUSTAINABLE CITIES AND COMMUNITIES